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DOES AN $I(z)$ CORRELATION EXIST FOR THE BACK-PART OF THE SHROUD BODY IMAGE?

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ABSTRACT. Nowadays it is not known if an $I(z)$ correlation exists for the back-part of the Shroud body image. This occurs because it is difficult to measure the cloth-body distances and to correlate them with the intensities of the image. By a scientific analysis we find a correlation with a slope that is different from the one related to the front-part of the above image.

The Shroud of Turin is an ancient linen that shows the frontal and the dorsal images of a man scourged and crucified. This cloth has been studied by high level technology [1] because many people venerate it as the burial of Jesus of the Gospels, whereas others denounce it as a medieval forgery [2].

Up to now, the "Shroud question" is unresolved. In fact, the scientists have not yet all the necessary answers for a complete knowledge of the above Linen [3–5].

Thanks to the work of the members of the Shroud of Turin Research Project [6–9] we know that the Shroud body image is consistent with:

i: a human body shape covered with a naturally wrapping cloth;
ii: the lateral distortions due, almost certainly, to the cloth wrapping;
iii: a correlation between the image intensity $I(z)$ of the front-part of the body image and the cloth-body distance z, well represented by a regression line.

As long ago as 1902, P.Vignon [10] noted a relation between the shading image and the evaluated cloth-body distance. In Fig.1, we show a photograph of the Shroud. Here, is already evident that the optical density is maximum in the contact areas and decreases with the above distance.

The function described in the item iii) is the sum of two contributions: the first is due to the natural absorption of light and/or heat, the second is related to the body shape presence. The first contribution is almost constant, whereas the second is uneven and yields the image:

$$I(z)_{front} = I_b + I_M[1 - z/(R_0)_{front}] \quad \text{for} \quad 0 \leq z \leq (R_0)_{front} \tag{1}$$

where the I_b value is the contribution due to natural effects, $I_b + I_M$ is the intensity in the areas at $z = 0$ and R_0 is the z value that makes $I(z) = I_b \approx const.$

This result has been obtained using a microdensitometer in only 13 image locations (the ones accurately identified by V. Miller, quoted in Ref. [11]) and, then, realising the fitting procedure.

By the analysis of this picture, a question remain still opened: does exist an $I(z)$ correlation also for the back-part of the Shroud body image?

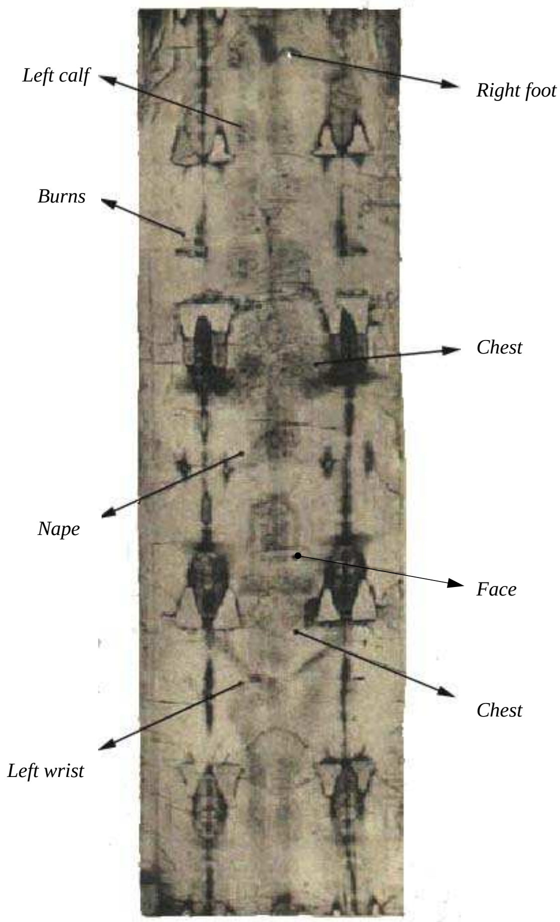

FIGURE 1. Black and white photograph of the Shroud of Turin.

Up to now nobody has given an answer. In fact, in any experiment, due to the expected cloth-body distances that are very small for the compression of the body on the cloth, it is very difficult to measure them and to correlate such distances with the corresponding I values.

In fact, measuring the thermal patterns of the body contact on cloth (obtained using the infrared imaging), it has been estimated (for a body of $\sim 75Kg$ weight) that the dorsal contact area is $\approx 2800cm^2$ whereas the frontal one is $\approx 1100cm^2$ [6]. In this case, the difference in the front/back cloth pressure ($\sim 0.35g/cm^2$ against $\sim 26.8g/cm^2$) of about two orders of magnitude leads us the conclusion that the estimates of the z distances are rather problematic. In fact, for the formation of the back-part of the Shroud body image the contact mechanism had a role more important with respect to the formation of the front-part image. Besides, it should be appropriate to take into account the natural irregularity in the disposition of the cloth on the body, that are of difficult evaluation.

These experimental difficulties in the measure of the (z, I) pairs have stimulated us to attain, by an actual and improved analysis, new and useful information on the $I(z)_{back}$.

Along this way, we point out that:

- **a:** the optical density in the no-image area is almost constant in all the linen. So as must be for the interaction between the e.m. radiation and cloth [3, 11];
- **b:** in the region where the back-part of the body image lies, the chemical modifications that yield the image are the same of the ones present in the front-part of the above-mentioned image: there are any fibrils with a yellowing which is of background and others with the optical density observed by Pellicori and Evans [12];
- **c:** the thickness of the yellowed linen forming the image is the same in both front-part and back-part of the body image [3, 13];
- **d:** the used technique that converts the shading image into relief lead to the expression: $I_b + (I_M)_{front} \approx I_b + (I_M)_{back}$ [6, 14];
- **e:** both the images have the density of the yellowed fibrils that decreases with the cloth-body distance. This trend is observed in all the front-part of the image. In the back-part it is clearly evident in the calf area [3].

All these conditions lead us to affirm that a correlation $I(z)$ also exists for the back-part of the body image. This statement has never been contradicted.

In such a function, similar to formula (1), the term that takes into account the natural oxidation and dehydration of the cellulose is again I_b (see Item a), so as I_M is the maximum contribution due to the body shape presence (see Item d). It is also necessary to take into account that the image intensity degrades from the areas with $z = 0$, where $I_b + (I_M)_{front} \approx I_b + (I_M)_{back}$, to the background value (I_b) through cloth-body distances that are different: $(R_0)_{back} < (R_0)_{front}$.

Therefore, the expression for the image intensity in the back-part could be:

$$I(z)_{back} = I_b + I_M[1 - z/(R_0)_{back}] \quad \text{for} \quad 0 \leq z \leq (R_0)_{back} \tag{2}$$

where $(R_0)_{back}$ the z distance that makes $I(z)_{back} = I_b$. In Fig 2 both the functions are represented: the (1) by a full line (front-part) and the (2) by a dash-dotted line (back-part).

As Fig. 2 shows the two correlations have different slopes. In fact, for $z < (R_0)_{back}$ of the cloth-body distance there are two values of the image intensity having $I(z)_{back} < I(z)_{front}$.

Since $(I_M)_{front} \approx (I_M)_{back}$, the differences between the functions (1) and (2) cannot be related to emission effects. This means that such differences are related to the attenuation effects. Really, these effects are more intense in the region where the back-image lies because $(dI/dz)_{front} = -I_M/(R_0)_{front}$ and $(dI/dz)_{back} = -I_M/(R_0)_{back}$, where the absolute value of the I_M/R_0 rate is larger in the region of the back-part with respect to the front-part of the Shroud body image.

This result is unexpected because the two, front and back, images have the same characteristics. Therefore, we have to consider others correlations that, respecting the two

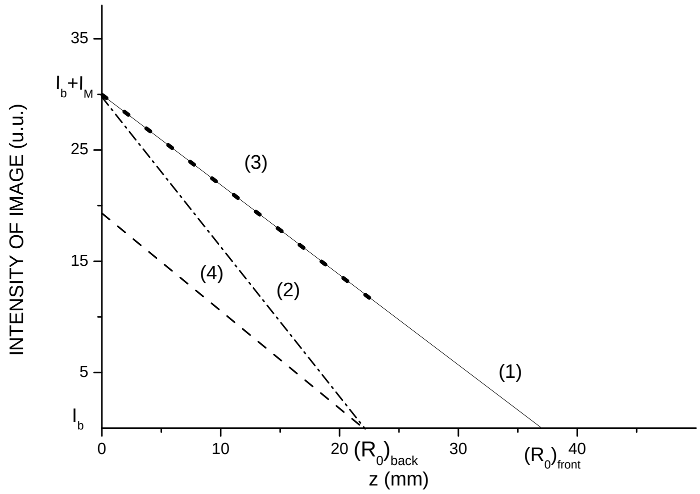

FIGURE 2. Intensity of the Shroud body image vs. cloth-body distance. The correlation (1) is related to the measurements; the functions (2), (3) and (4) are hypothesis of possible correlations relatively to the back-part of the body image. The $(R_0)_{front} = 37mm$ [6], while the $(R_0)_{back}$ is an arbitrary value. The zero value, in the unnormalized units of I, represents the average cloth background intensity.

$(0, I_M + I_b)$ and $((R_0)_{back}, I_b)$ pair of values, have the same slope of the one relative to the front-part of the body image.

In this way, there are two possible different functions with the same slope:

$$\text{(3)} \qquad \begin{cases} I(z)_{back} = I_b + I_M[1 - z/(R_0)_{front}] & for\ 0 \leq z < (R_0)_{back} \\ I(z)_{back} = I_b & for\ z = (R_0)_{back} \end{cases}$$

and

$$\text{(4)} \qquad \begin{cases} I(z)_{back} = I_b + I_M & for\ z = 0 \\ I(z)_{back} = I_b + I_M\{[(R_0)_{back} - z]/(R_0)_{front}\} & for\ 0 < z \leq (R_0)_{back} \end{cases}$$

Both the functions have the same attenuation effects for the back-part, like the one for the front-part of the Shroud image: $dI(z)_{back}/dz = -I_0/(R_0)_{front}$.

The comparison of such two functions is reported in Fig.2: the expression (3) is represented by the dotted line and expression (4) by dashed line. The two correlations show points of singularity that, for the back-part of the Shroud image, mean abrupt changes in the values of the image intensity. For the function (3) the change could be in proximity of the zones with $z = (R_0)_{back}$, while for the (4) near the contact areas (where $z = 0$).

We can affirm that on the back image of the Shroud, rapid changes of the intensity do not appear in the $I(z)$ distribution values. However, there are areas that in relation to the background have lower values of the optical density with respect to other areas. They

FIGURE 3. The face: particular of the Shroud body image. To his sides are evident the rapid changes in the intensity of image values.

appear as stripes (about $2.5cm$ each) running longitudinally on the cloth. As Fig. 3 shows these abrupt changes in the I values are visible at the sides of the face (front-part of the body image). This occurs because different lots of thread have been used in the manufacture of the cloth [6, 11].

With this state of affairs, the more suitable $I(z)$ correlation to describe the variation of the optical density in the region where the back-part of the image lies is represented by equation (2).

In conclusion this result, due to the exclusion of the correlations (3) and (4), means that the attenuation effects are different in the formation of the back and front images. In fact, it is clear that in the Shroud body image formation the differences in the optical density distribution, measurable on the linen, are not due to differences in the emission (see Item d) but at different attenuation effects.

Therefore, we know that beyond the differences inside the same (front or back) image there are also differences between the two images.

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